Interim (5 km) High-Resolution Wind Resource Map for South Africa

Mortensen, Niels Gylling; Hahmann, Andrea N.; Hansen, Jens Carsten

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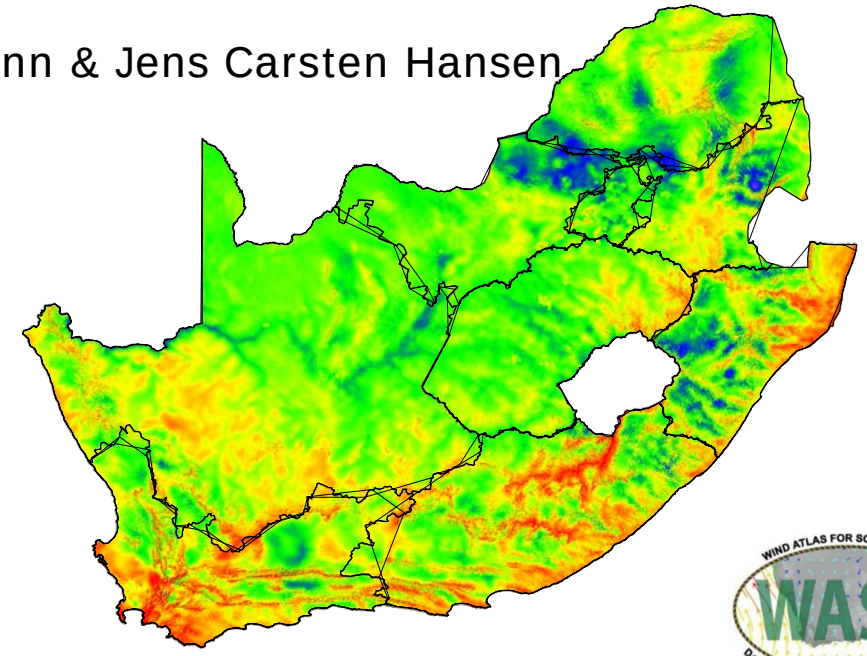
Andre Otto
SANEDI

Niels G Mortensen, Andrea N Hahmann & Jens Carsten Hansen
DTU Wind Energy

Eugéne Mabille and Eric Prinsloo
CSIR



Windaba 2017
Cape Town, South Africa

South Africa Wind Energy Program
SAWEP 1 (2007 to 2010)

- Funded by the GEF USD 2 mill with the Dept. of Energy as the Executing Entity/Implementing Partner and supported by the UNDP South Africa Country Office.
- Developed and fund Green Power Guarantee Scheme that assisted City of Cape Town to enter into 20 year PPA with the Darling Wind Power company (SA's 1st IPP wind farm)
- Initiated and supported with Danida co financing the Wind Atlas for South Africa Phase 1 (WASA 1 2009 to 2014, Western Cape and parts of NC, EC):

  - WASA team (CSIR, UCT (CSAG), SAWS, DTU Wind Energy, SANEDI)
  - 10 Wind Measurement stations, 9 operating since Sept 2010
  - online graphs and data download
  - customization and application of the WRF model for wind resource assessment, verified wind atlas and database
  - 1st large scale high resolution wind resource map and used in the DEA SEA project identification of wind hot spot areas
  - **Independent, scientific, confirmation SA has an excellent wind resource** http://www.wasaproject.info/docs/WASABooklet.pdf
  - **wind time series data used in PV/Wind Aggregation study (wind on par with solar)** https://www.csir.co.za/study-shows-abundance-wind-and-solar-resources-south-africa
  - leveraged additional support of the Danish Government for WASA 2 (2014 to 2018, KZN, Free State and remaining parts of EC)

- Supported (start up) business plan for SAWEA. SAWEA today fully fledged Wind Energy Industry Association
- Supported DEA/SEA Phase 1

SAWEP 2 (2015 – 2019)

- SAWEP 2 is funded by the GEF (USD3.5 mill) with the Dept of Energy as the Executing Entity/Implementing Partner and project management by SANEDI with UNDP South Africa Country Office support (procurement, financial management)

- Project Steering Committee: DoE (chair), DST, DEA, DTI, DHET, UNDP, SANEDI

- Project Coordination Unit (PCU: Siyabonga Zondi (DoE), Andre Otto PM (SANEDI)

SAWEP 2 Implementation

- Implementation **started** Aug 2016

- **Objective**: to assist the Government and industry stakeholders overcome strategic barriers to the successful attainment of South Africa's Integrated Resource Plan target of 3,320 MW of wind power generation online by 2018/19

- **Components** :
    1. Monitoring and Evaluation of the implementation of local content requirements;
    2. Resource-mapping and wind corridor development support for policy-makers;
    3. Support for the development of small-scale wind sector an
    4. Training and human capital development for the wind energy sector

Comp 1: Monitoring and Evaluation of the implementation of local content requirements

- Focus area: Support RE IPPPP through review and analysis of the current socioeconomic development approach and use of appropriate modelling/tool to demonstrate and evaluate the impact with recommendations towards the achievement of optimal socio economic benefit.

- Projects:

  - Project 1.1 An assessment and analyses of the impact of the RE IPPPP on the South African Economic Development (procurement underway)

Comp 2: Resource-mapping and wind corridor development support for policy-makers

- Institutionalization of WASA through extension of WASA to the remaining areas of the Northern Cape province, including rest of South Africa
- Support DEA SEA Phase 2 identification of wind development zones

- Projects:

  - 2.1 WASA 3 (4 additional masts, 2 years wind measurement, refining, validation WRF model, Wind atlas, database, time series data, Resource map) and expanding to rest of South Africa)
    - Commenced Sept 2017 to July 2020
  - 2.2 Support DEA SEA Phase 2 – Interim 5 km High Resolution Wind Resource map for South Africa (Oct 2017)

Comp 3: Support for the development of small-scale wind sector

- Options that have the best prospects for implementation in support of the small-scale wind sector outlined, pilot project for small-scale wind implemented

- Projects:
  - 3.1 Review, assess and analyse the small scale wind energy sector, SWOT Analysis, Small Scale REIPP review, Stakeholder workshop, Specification and technology configuration for a small scale wind energy pilot project
    - Commenced October, service provider: Carsten H Laugesen

Comp 4: Training and human capital development for the wind energy sector

- To define and describe SAWEP 2 support for Wind Energy Training, Education, Skills and Capacity Development in South Africa with the highest impact, including updating of the SAWEP 2 Project document Component 4, outputs, activities and Project Results Framework were necessary.

- Projects:
  - 4.1 Status and Analysis Wind Energy Training Education Skills and Capacity development.
    - Commenced September 2017, service provider: Sean Gibson
    - WindAc Africa 2017 (R400,000) and Windaba 2017 support (R85,000)

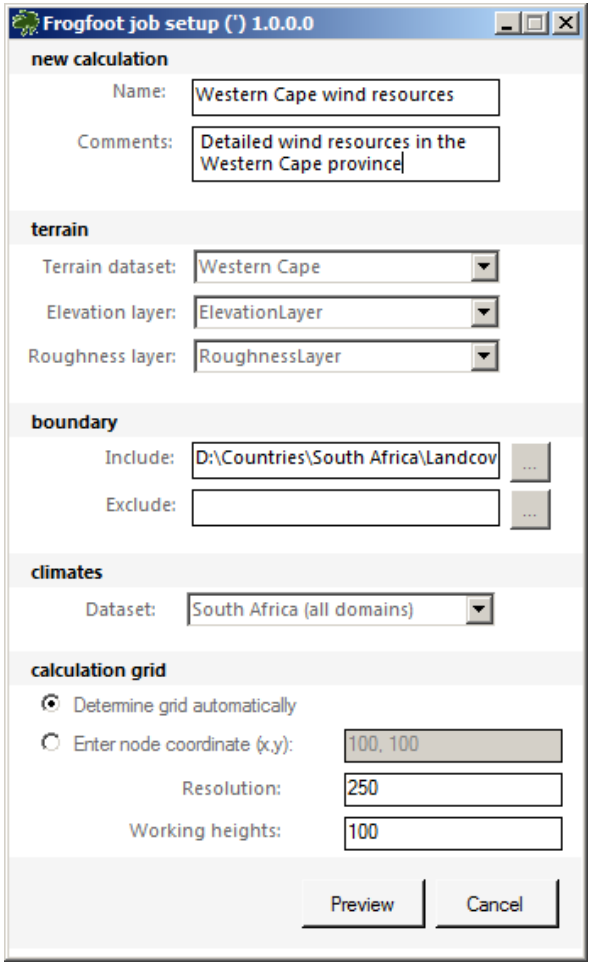
Modus Operandi

Not to duplicate or to compete, but to enhance and add value through effective collaboration and partnership

Interim (5 km) High-Resolution Wind Resource Map for South Africa

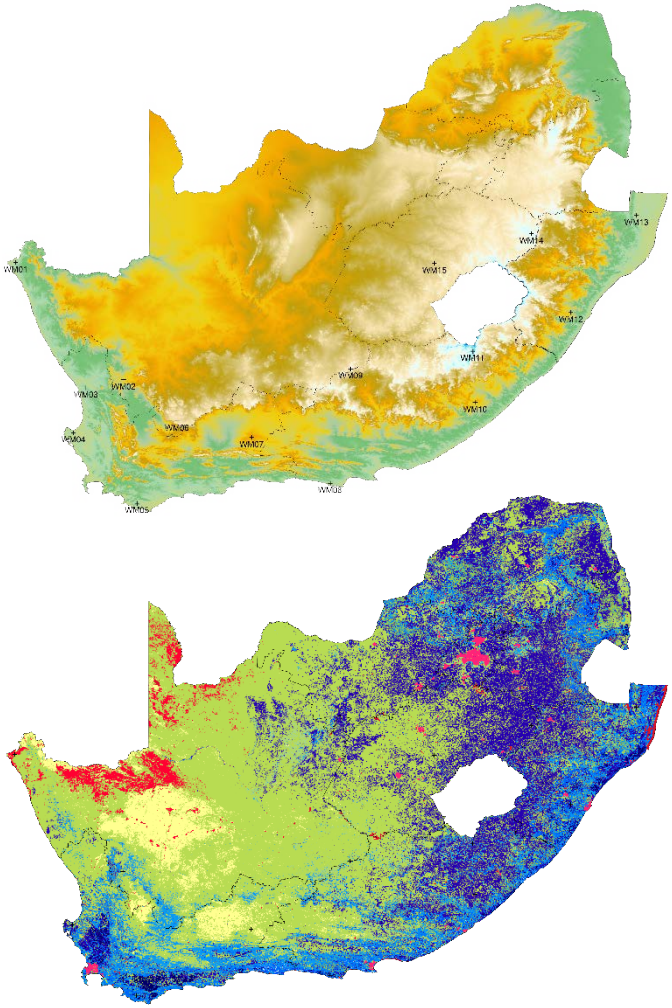
Updated wind resource mapping methodology

- *Frogfoot* implementation of WAsP
  - Database of wind climates
  - Database of elevation maps
  - Database of roughness maps
- Principle of operation
  - Batch mode operation
  - Distributed computing
  - Wind atlas interpolation to every prediction site.
  - Results in MySQL database
  - Export to GIS formats
- WAsP standard modelling
  - Industry-standard model
  - Linearized flow model
  - Default parameters

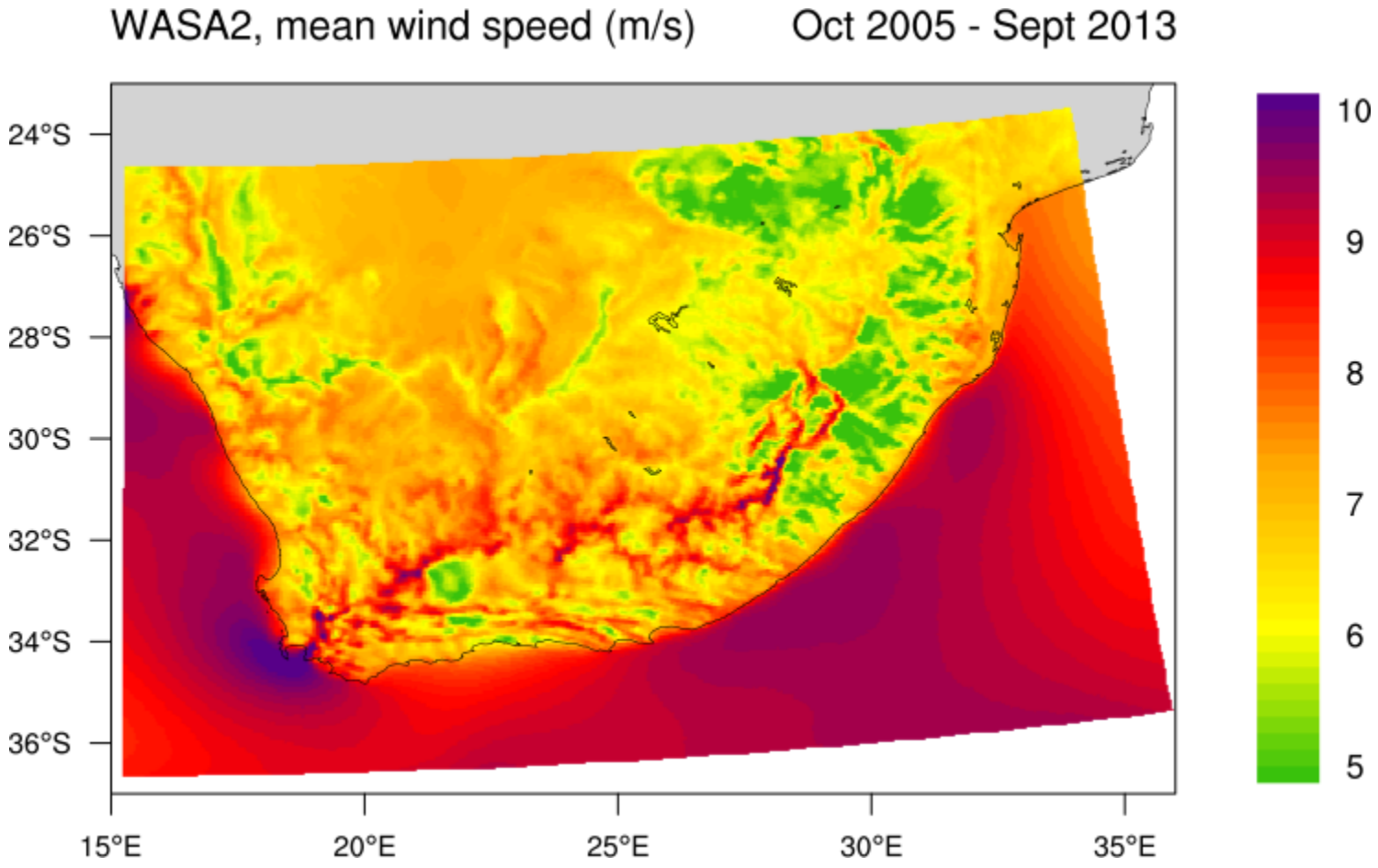


Available input data for modelling

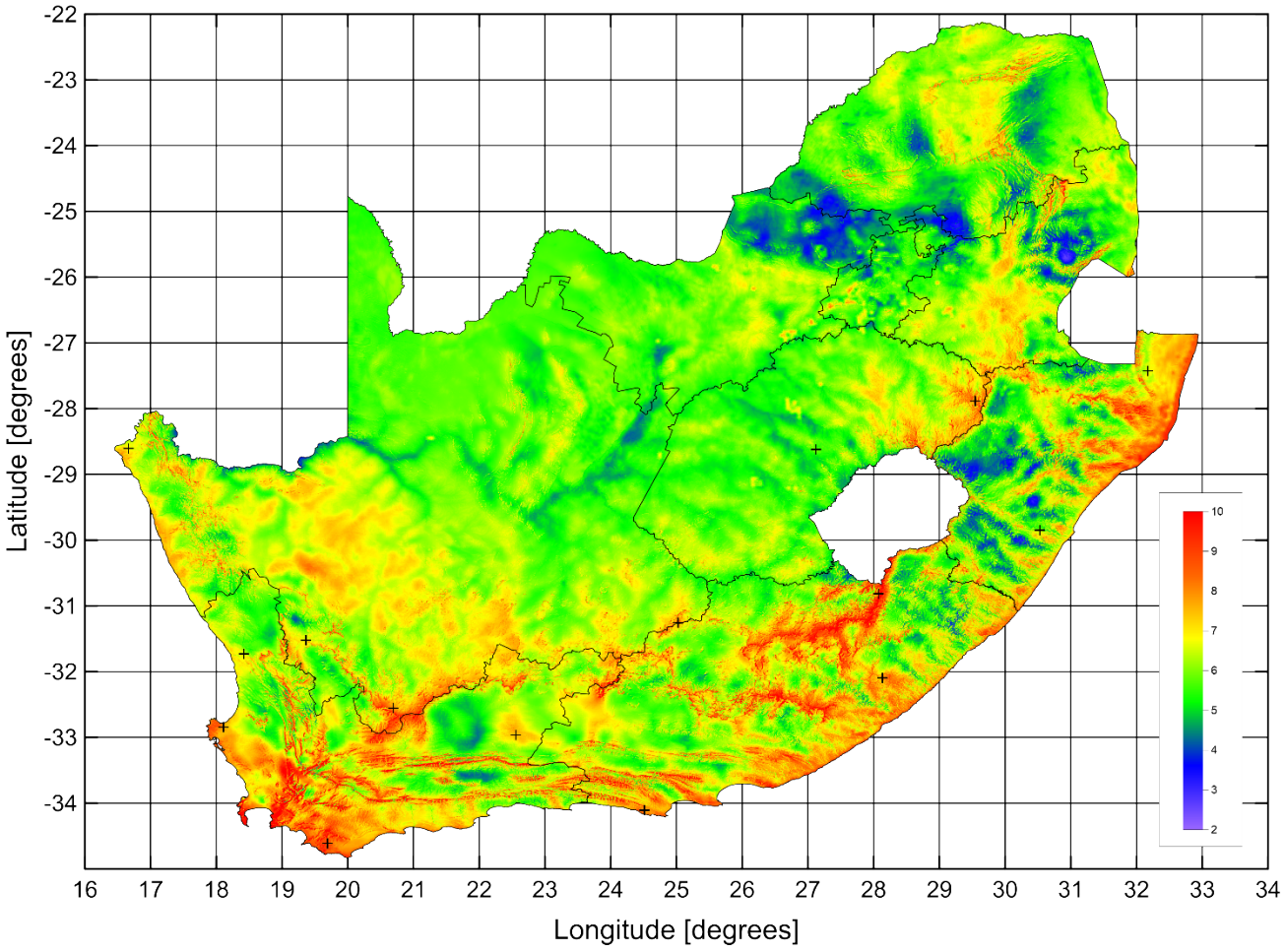
- Validated Numerical Wind Atlas
  - WRF mesoscale model
  - Virtual mast for every 3-5 km
  - WASA 1 domain: 3 km
  - All of South Africa: 5 km
- Elevation
  - 100-m elevation grid from space shuttle Endeavour (SRTM+, NASA version 3).
- Land cover
  - 300-m land cover grid derived from ESA GlobCover 2009.
  - Transformation table for z_0



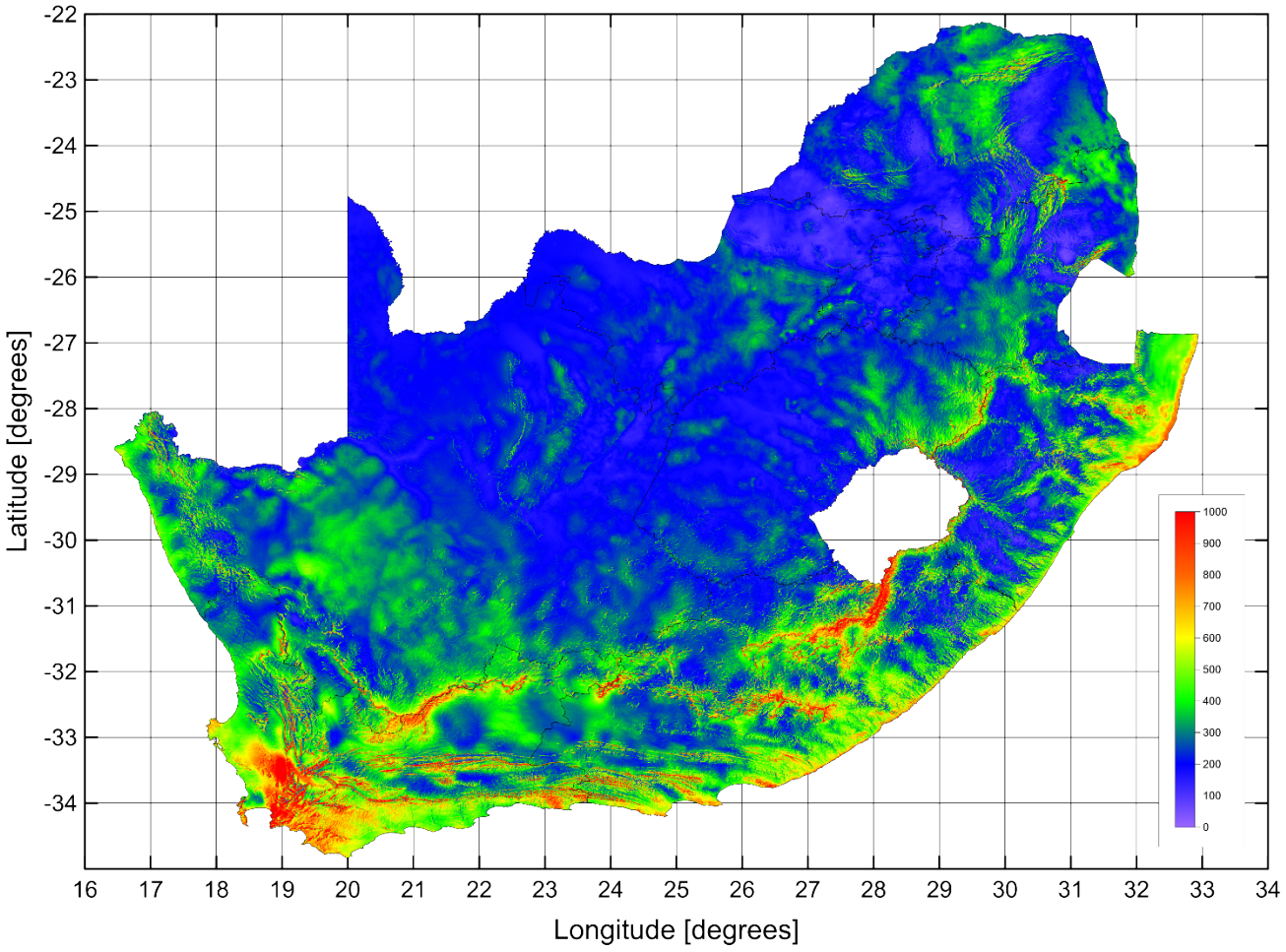
WRF 5-km simulated winds



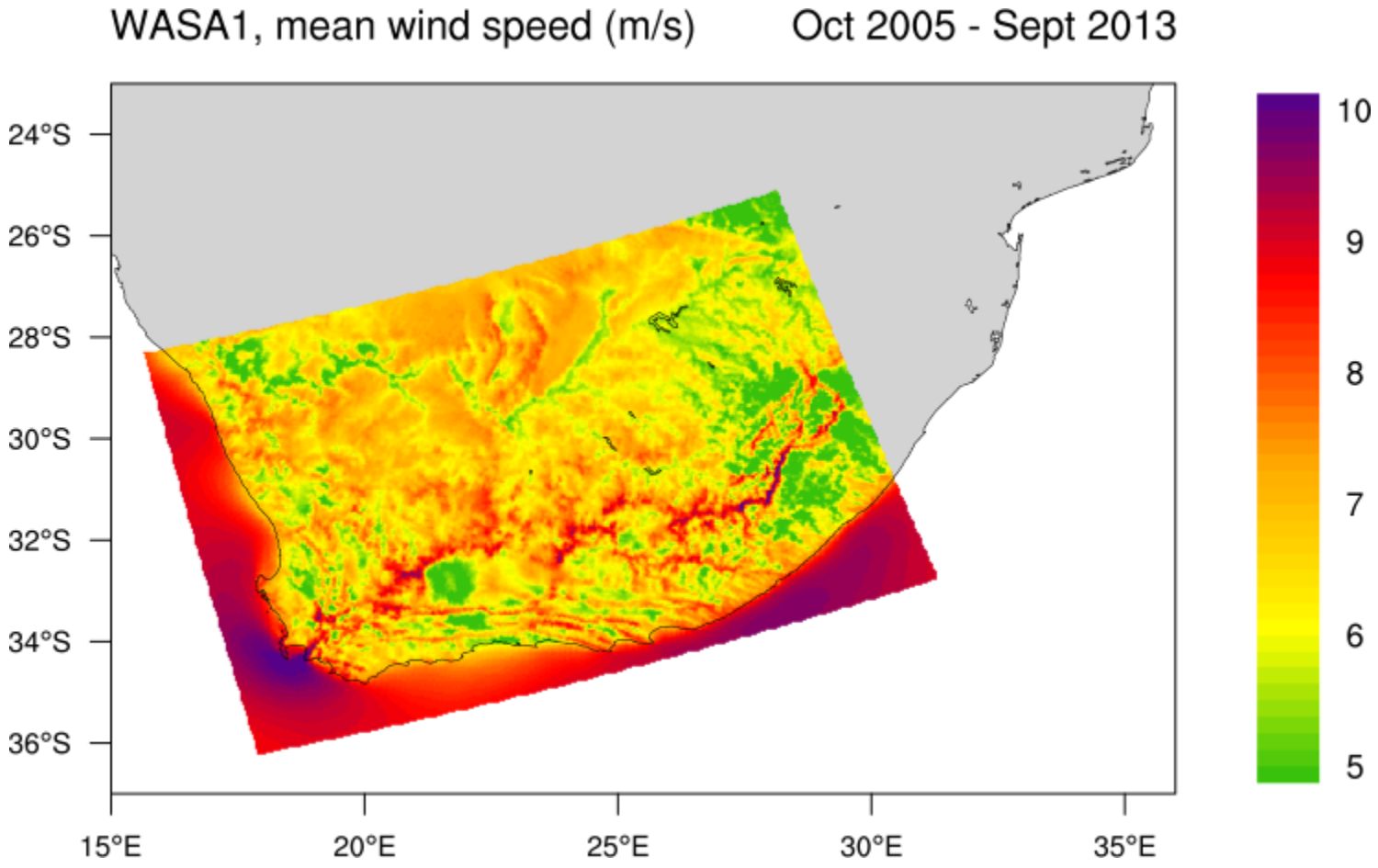
South Africa wind speed @ 100 m



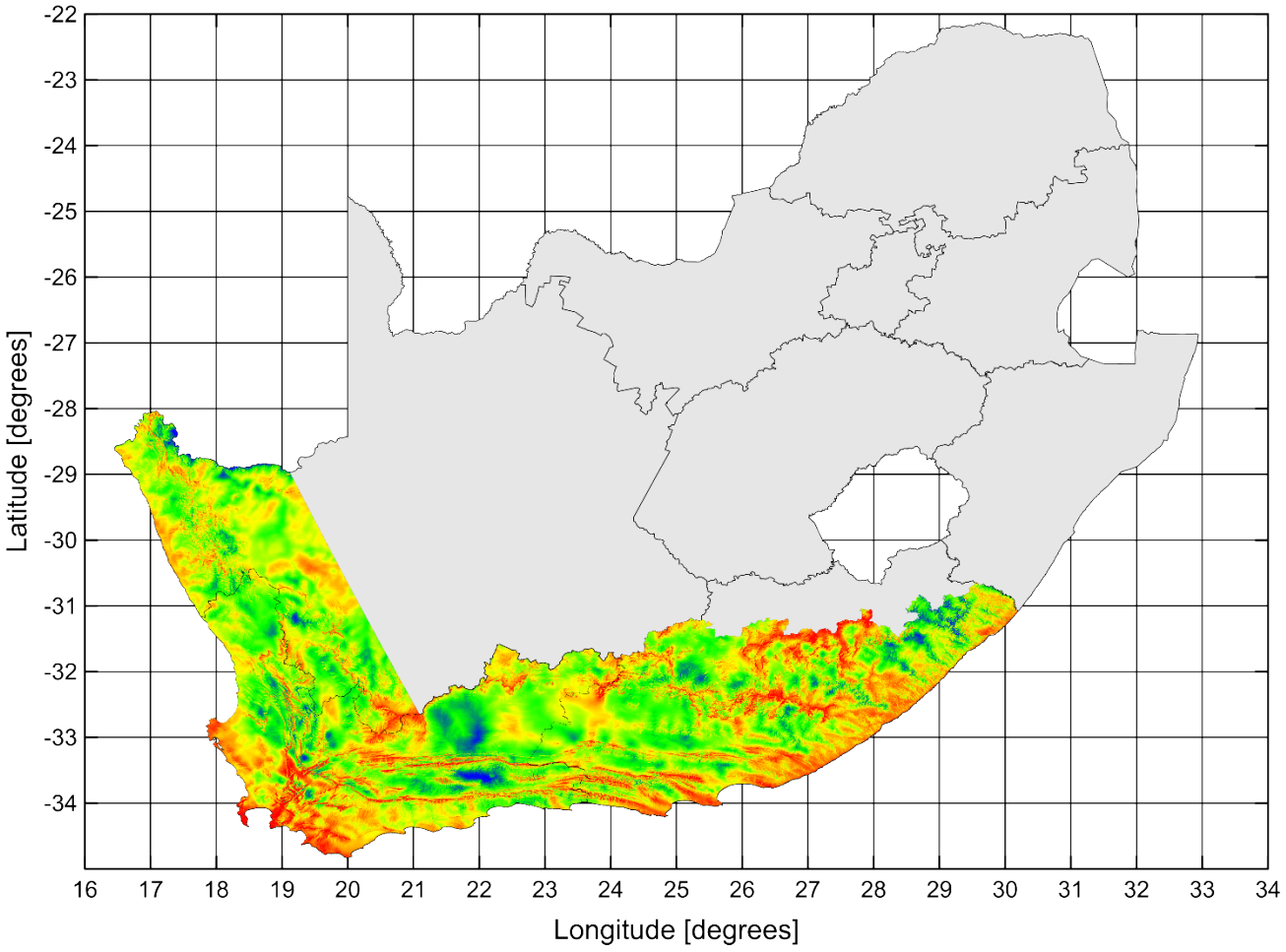
South Africa power density @ 100 m



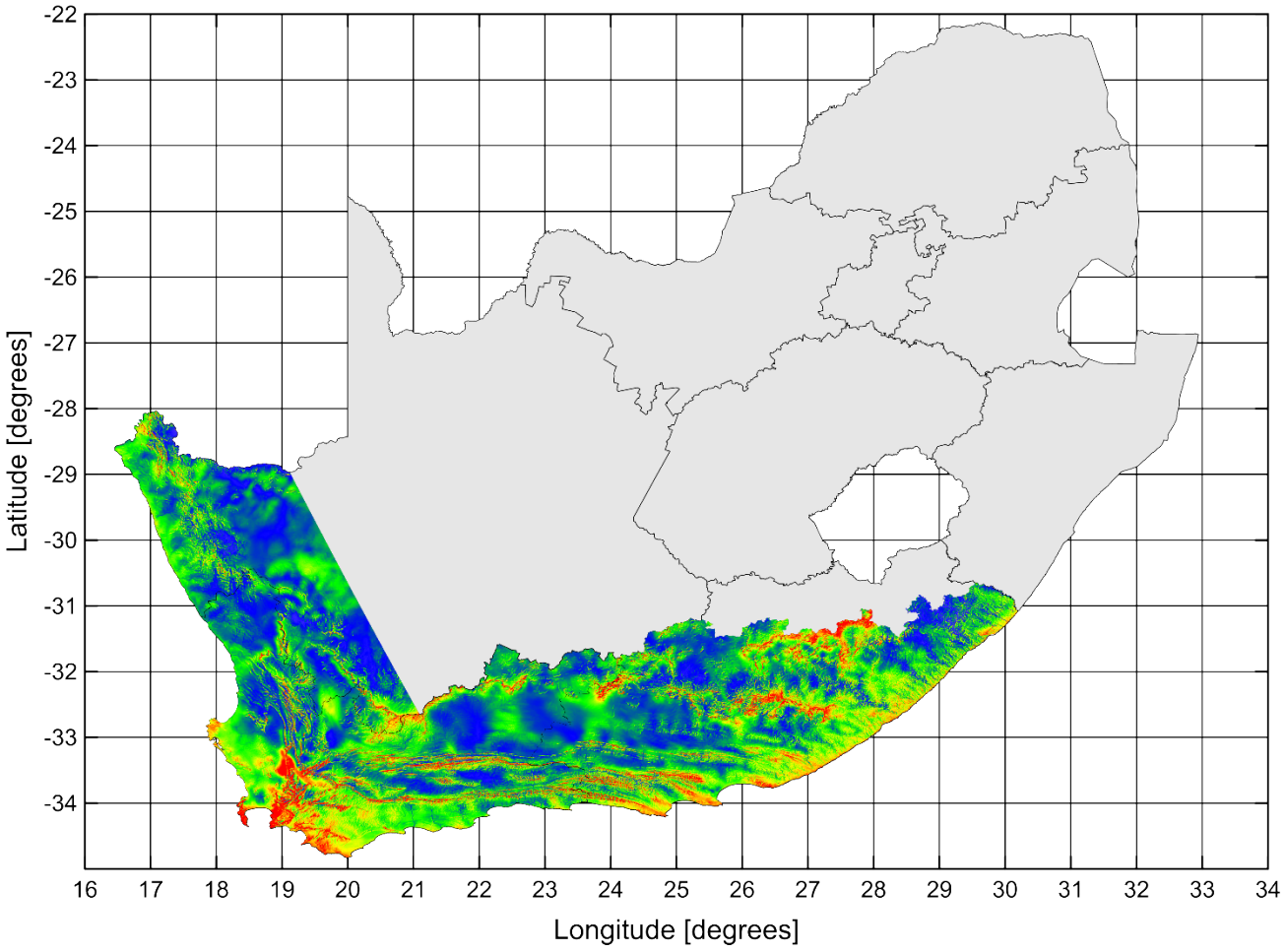
WRF 3-km simulated winds



WASA1 wind speed @ 100 m



WASA1 power density @ 100 m

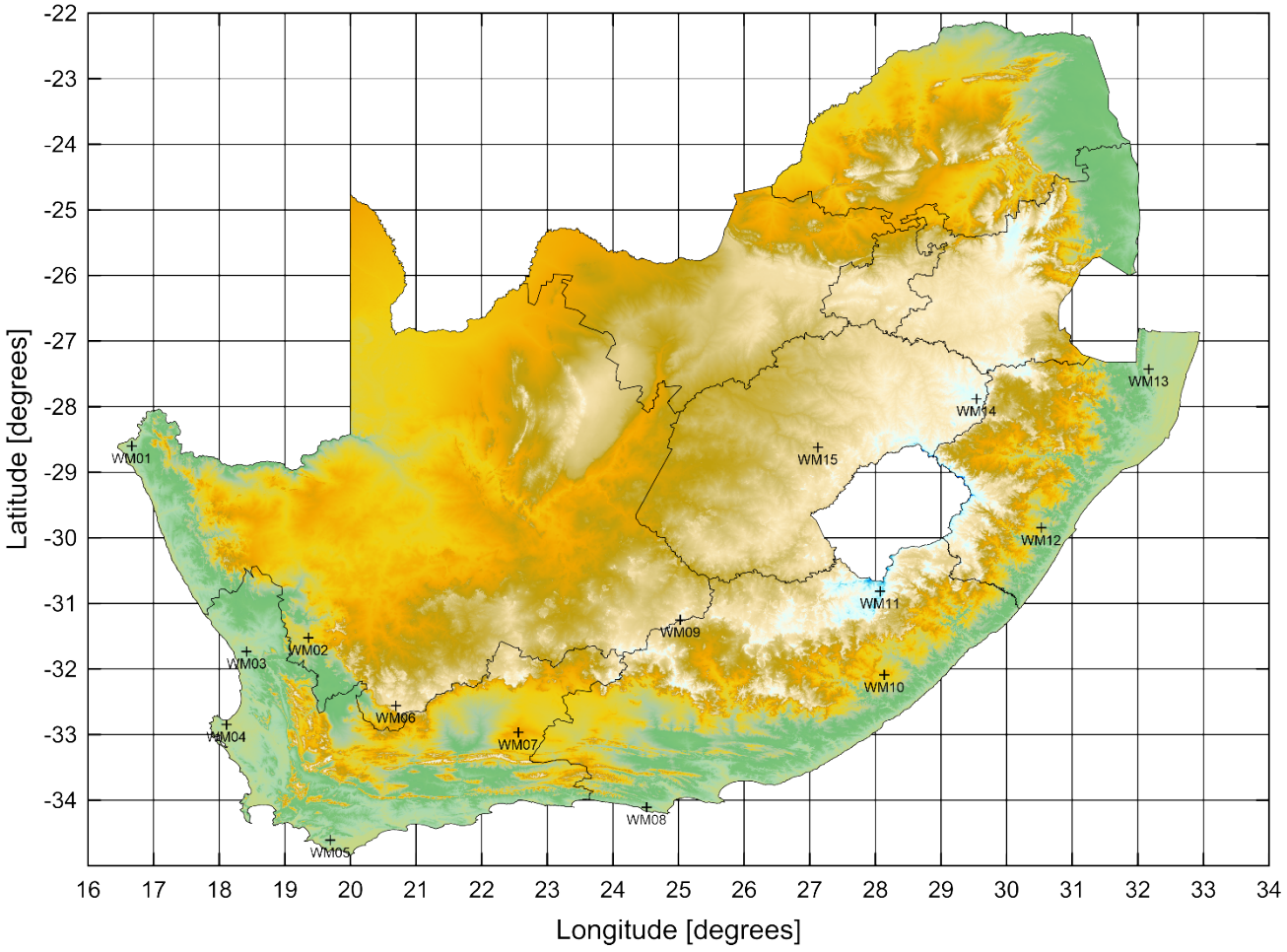


Interim High-Resolution Wind Resource Map

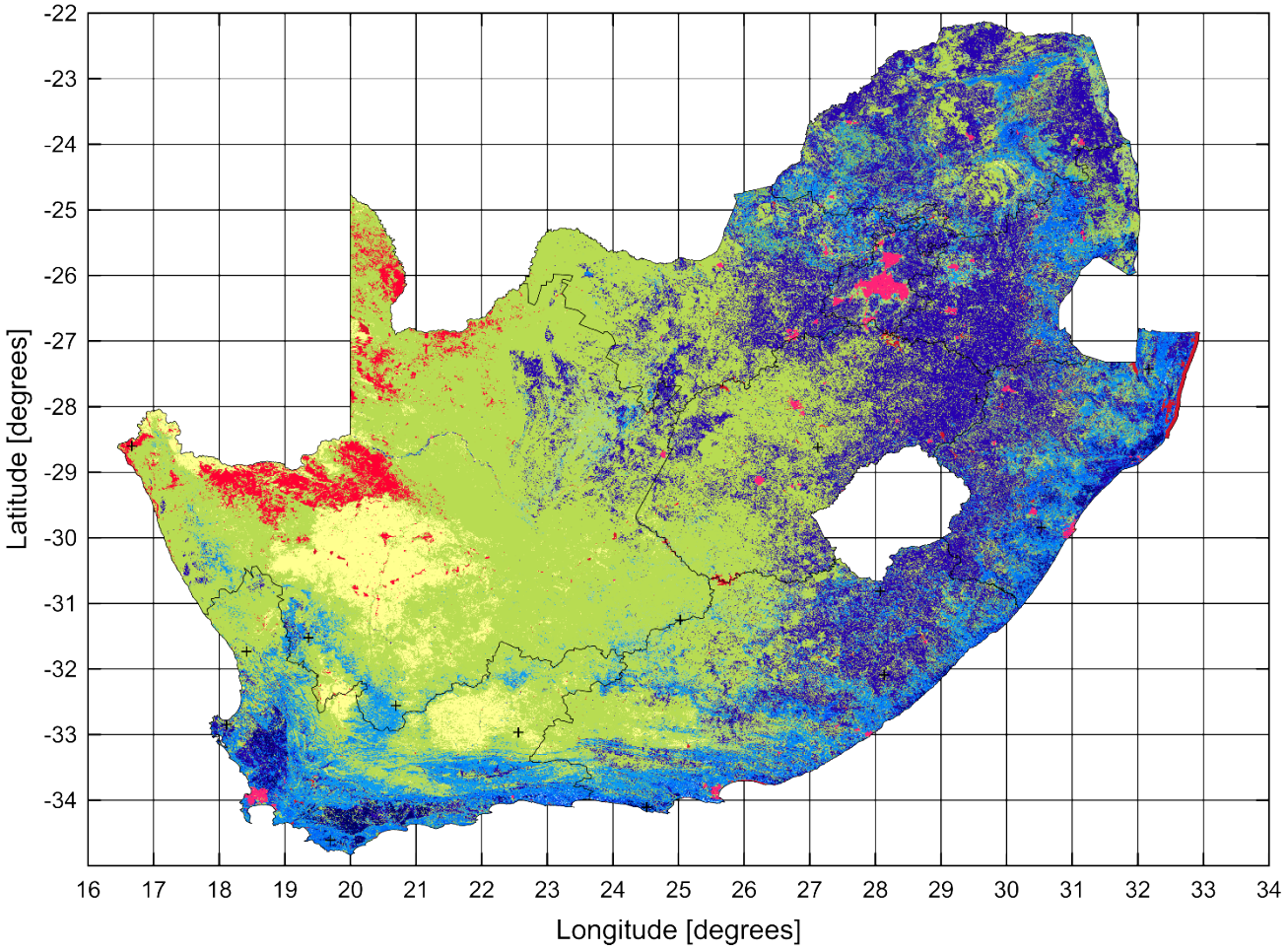
- **Detailed wind resource maps**
  - 250 × 250 m grid results
  - Modelling resolution ~1 m
  - 50, 100 and 200 m a.g.l.
  - ArcGIS ASC output format
- Mean wind speed *U*
  - 10 min average in [ms^{-1}]
- Mean power density *P*
  - 10 min average in [Wm^{-2}]
  - Site-specific air density
- Elevation *z*
  - Meters above sea level [m]
- Ruggedness index RIX
  - WAsP standard parameters

- **Database of wind climates**
  - 250 × 250 m grid results
  - 50, 100 and 200 m a.g.l.
  - Sector-wise results (× 12)
  - ASCII TXT output format
- For each site, height and sector
  - Weibull *A* parameter [ms^{-1}]
  - Weibull *k* parameter
  - Frequency of occurrence
- Data for calculation of
  - Specific power density
  - Wind turbine energy yield
  - Wind turbine capacity factor
  - and much more…

South Africa elevation

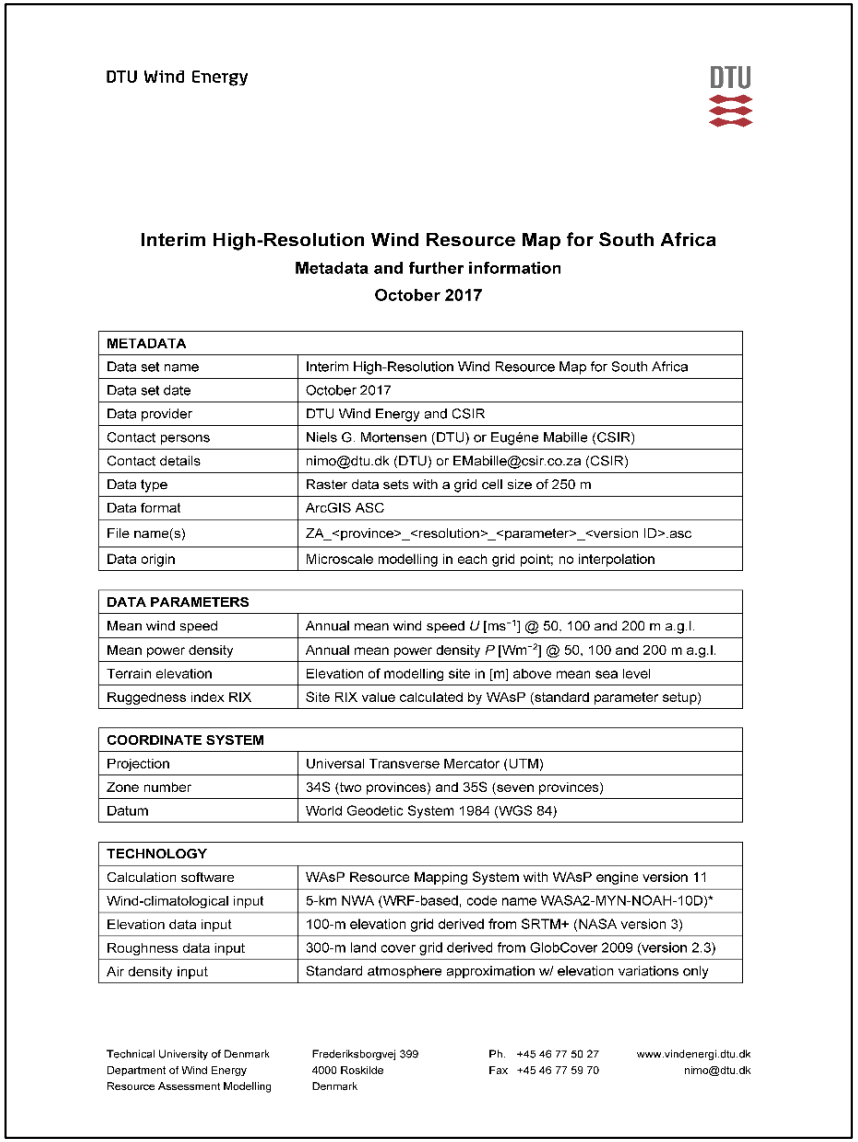


South Africa land cover



Metadata documents for wind resource data sets

- Metadata for data sets
  - Data set specifications
  - Data provider
  - Contact information
- Data set parameters
- Coordinate system
- Technology (models & data)
- Detailed notes
  - Purpose
  - Methodology
  - Limitations
  - Available documentation
  - Acknowledgements
  - Disclaimer
  - Four maps of *U*, *P*, *z* and RIX



DTU Wind Energy

Interim High-Resolution Wind Resource Map for South Africa

Metadata and further information

October 2017

METADATA	
Data set name	Interim High-Resolution Wind Resource Map for South Africa
Data set date	October 2017
Data provider	DTU Wind Energy and CSIR
Contact persons	Niels G. Mortensen (DTU) or Eugéne Mabille (CSIR)
Contact details	nimo@dtu.dk (DTU) or EMabille@csir.co.za (CSIR)
Data type	Raster data sets with a grid cell size of 250 m
Data format	ArcGIS ASC
File name(s)	ZA_<province>_<resolution>_<parameter>_<version ID>.asc
Data origin	Microscale modelling in each grid point; no interpolation

DATA PARAMETERS	
Mean wind speed	Annual mean wind speed U [ms^{-1}] @ 50, 100 and 200 m a.g.l.
Mean power density	Annual mean power density P [Wm^{-2}] @ 50, 100 and 200 m a.g.l.
Terrain elevation	Elevation of modelling site in [m] above mean sea level
Ruggedness index RIX	Site RIX value calculated by WAsP (standard parameter setup)

COORDINATE SYSTEM	
Projection	Universal Transverse Mercator (UTM)
Zone number	34S (two provinces) and 35S (seven provinces)
Datum	World Geodetic System 1984 (WGS 84)

TECHNOLOGY	
Calculation software	WAsP Resource Mapping System with WAsP engine version 11
Wind-climatological input	5-km NWA (WRF-based, code name WASA2-MYN-NOAH-10D)*
Elevation data input	100-m elevation grid derived from SRTM+ (NASA version 3)
Roughness data input	300-m land cover grid derived from GlobCover 2009 (version 2.3)
Air density input	Standard atmosphere approximation w/ elevation variations only

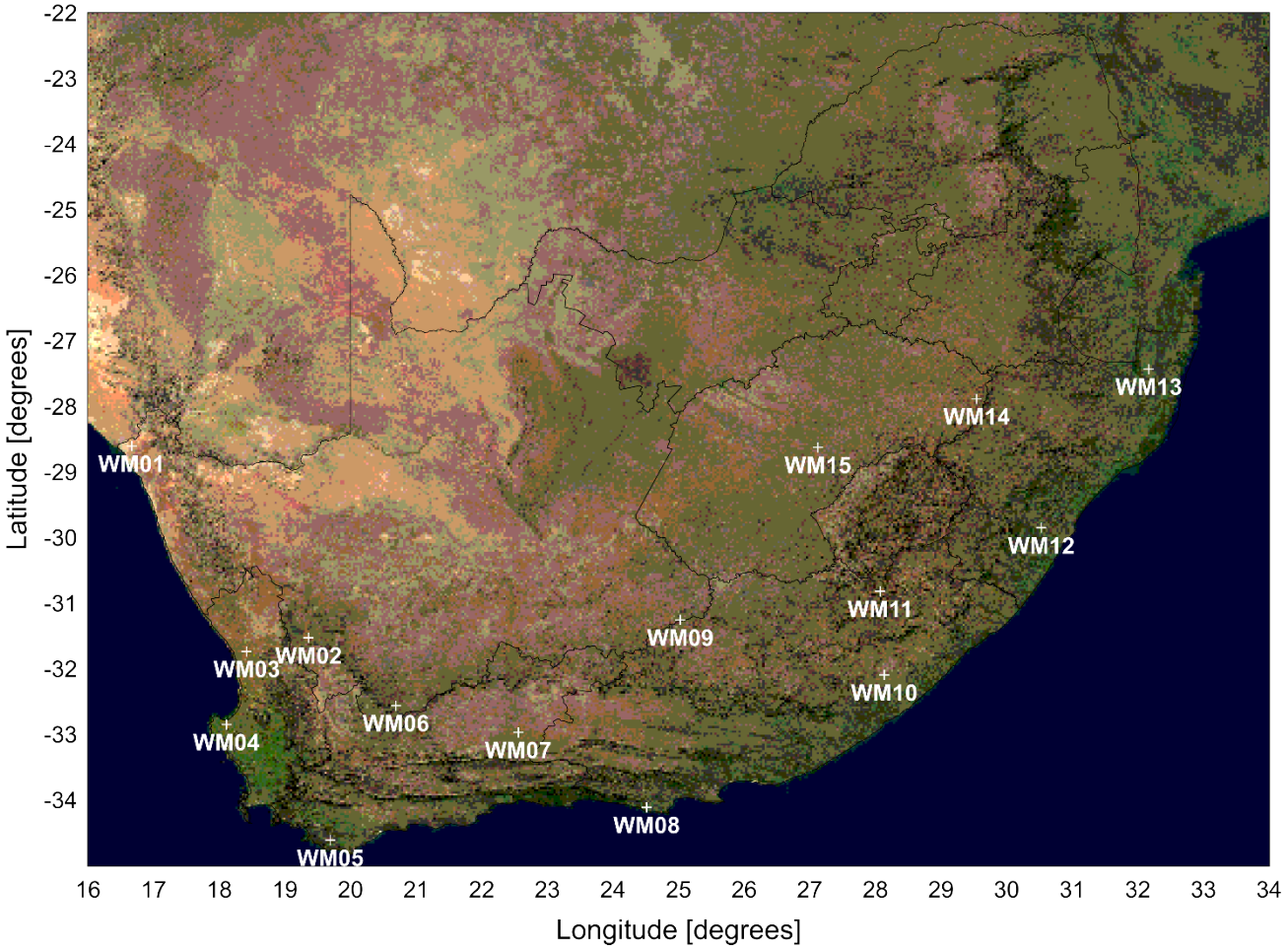
Technical University of Denmark
Department of Wind Energy
Resource Assessment Modelling

Frederiksborgvej 399
4000 Roskilde
Denmark

Ph. +45 46 77 50 27
Fax +45 46 77 59 70

www.vindenergi.dtu.dk
nimo@dtu.dk

Wind Atlas for South Africa masts



Comparison - measured and modelled generalised winds @ 62 m

WASA mast	Observed wind U_0	WASA1 wind U_1	$U_1 - U_0$	WASA-2017 wind U_2	$U_2 - U_0$
	[ms^{-1}]	[ms^{-1}]	[%]	[ms^{-1}]	[%]
WM01	6.12	5.66	-8%	6.02	-2%
WM02	5.94	5.90	-1%	6.32	+6%
WM03	6.55	5.48	-16%	5.94	-9%
WM04	6.68	6.54	-2%	6.59	-1%
WM05	8.10	7.31	-10%	7.47	-8%
WM06	7.05	6.73	-5%	7.69	+9%
WM07	6.92	6.02	-13%	6.80	-2%
WM08	7.18	6.89	-4%	6.91	-4%
WM09	7.48	7.38	-1%	7.64	+2%
WM10	6.36	6.30	-1%	6.85	+8%
MAPE			6%		5%
All (signed)			−6%		0%

Wind farm planning and development (caution!)

- Identification and ranking of potential wind farm sites.
- Initial analyses and design
- Project planning
- Pre-feasibility studies
  - Resource assessment
  - Some site assessment
- Design of measurement campaign
  - Number of masts
  - Siting of masts
  - Orientation of sensor booms
  - Mounting of lightning rod and navigation lights.

Summary and conclusions

- Wind resources in South Africa
  - Large-scale: ~1.22 mio. km2
  - High-resolution: 250-m grids
  - Results in public domain
- Data sets to become available
  - Detailed wind resource maps
  - Database of wind climates
  - Three heights at every site
- Data sets specifically developed for
  - Strategic Environmental Assessment (SEA)
  - WF planning and development
- Validation and QA in progress
  - Software development phase
  - Comparisons at WASA masts

- Preliminary validation of WASA1 (3-km) to WASA2 (5-km):
  - Mean absolute percentage error (MAPE) decreases 15%
  - Spread decreases by 40%
  - Bias is almost 0%!
- WASA 2 and 3 focus areas
  - Land cover data & modelling
  - Long-term extrapolation
  - Atmospheric stability
  - Adaptation of modelling
  - Uncertainty modelling

Acknowledgements

The Wind Atlas for South Africa (WASA) project is an initiative of the South African Government – Department of Energy (DoE) and the project is co-funded by

- Royal Danish Embassy (WASA 1 and WASA 2)
- GEF through the South African Wind Energy Programme (SAWEP 1 &2)
- With UNDP Country Office support

WASA Project Steering Committee:

DoE (chair), DEA, DST, UNDP, Danish Embassy, SANEDI

Further information

Department of Energy
Siyabonga Zondi
PM Renewable Energy Initiatives
Siyabonga.Zondi@energy.gov.za

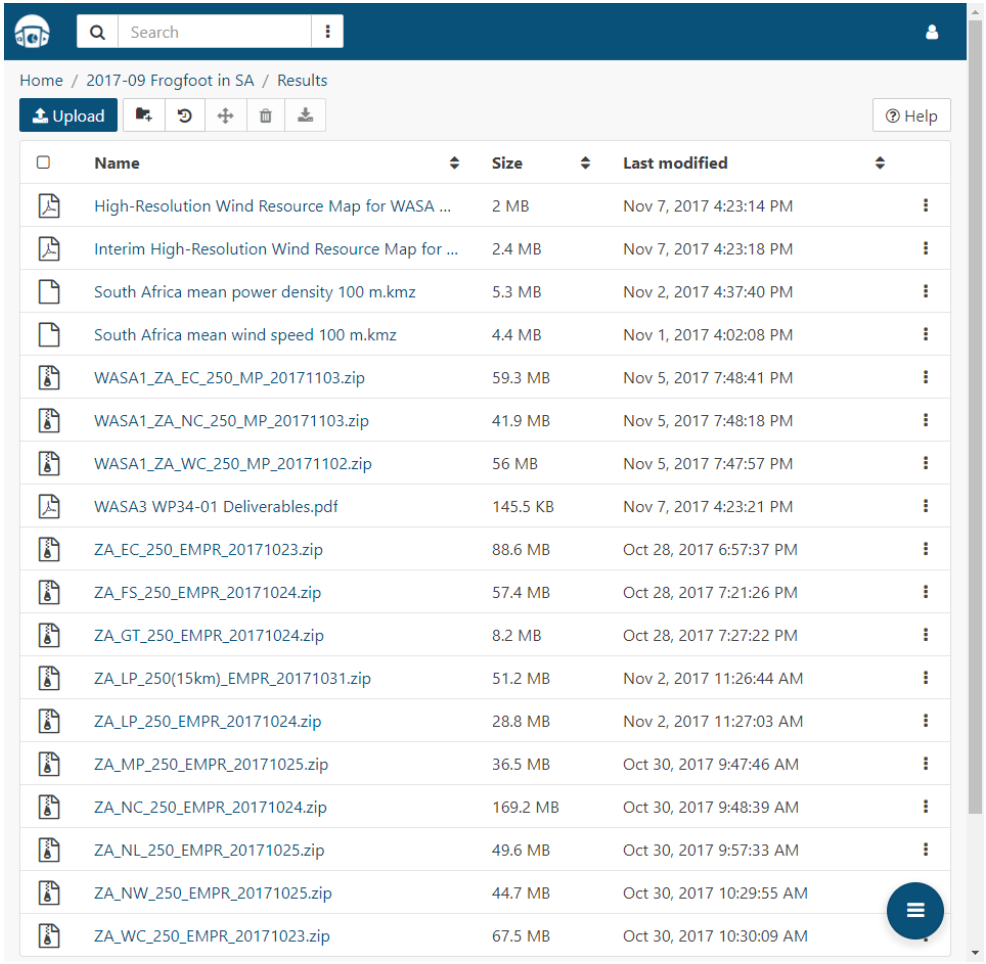
Technical enquiries:
SANEDI
Andre Otto
PM SAWEP 2
andreo@sanedi.org.za

SANEDI WASA site
www.wasaproject.info

WASA Online graphs
www.wasa.csir.co.za

WASA download site
http://wasadata.csir.co.za/wasa1/WASAData

Files.dtu.dk – Results folder



Files.dtu.dk – Database folder